

Asia Technology

Why mini LED display technology is set to take off

- ◆ Mini LED, a new display technology, is set to take off this year; we forecast a 2020-26e shipment CAGR of 60%
- ◆ It is already being used in TVs, and Apple is about to adopt the technology in iPads and MacBooks – a turning point
- ◆ We look at who stands to benefit the most in the supply chain

An exciting new technology. This report introduces the mini light-emitting diode (LED) technology that is about to start competing with liquid crystal display (LCD) and organic light-emitting diode (OLED), the existing technologies that dominate the display industry. Mini LED offers major advantages such as a better range of colours, a higher contrast ratio, and a narrower bezel (the border between the screen and the frame). The problem is cost. The cost of mini LED is now about 2x higher than that of OLED, and 3x higher than traditional LCD. We think costs will fall sharply over the next 2-3 years, paving the way for rapid expansion of mini LED and the introduction of an even more advanced technology – micro LED – that we think will eventually dominate the display industry.

Products – the Apple factor. Mini LED has already made its debut on the tech stage, mainly in TVs. We think Apple's (AAPL.US, USD124.74, Hold) decision to use the technology in iPads and MacBooks this year will be a major turning point. We think the major growth opportunity is in medium-size display applications such as notebooks, tablets, and automotive applications. We forecast that the penetration rate of mini LED in TVs will reach 5% in 2021e and 10% in 2022e; for medium-sized applications in general, we think penetration will rise to 2% and 7% in the same years. We forecast an overall mini LED shipments CAGR of 60% over 2020-26e.

Who stands to benefit most? The display supply chain is long and complex. Some parts of it should benefit more from mini LED than others, especially at the initial stage, when high costs and low yields will represent major challenges. We prefer segments likely to be less affected by these issues, such as LED testing and sorting solution providers, and display lamination. This thematic report should be read in conjunction with our initiations on four Taiwanese companies that we believe have a major role in the mini LED supply chain – FitTech: [Initiate at Buy: Ready to ride the mini LED wave](#), GIS: [Initiate at Buy: Displaying positives, major drag gone](#), TSMC: [Initiate at Hold: The lift from mini LED will take time](#), and Radiant: [Initiate at Hold: Stable for now but lacks a catalyst](#).

Company	Ticker	Currency	Current price	TP	Rating	Upside/downside	Market cap (USDm)	EPS y-o-y 2021e	2022e
Radiant	6176	TWD	118	133	Hold	12.7%	1,998	10%	15%
TSMC	6278	TWD	115	120	Hold	4.3%	1,211	21%	23%
GIS	6456	TWD	113	168	Buy	48.7%	1,375	27%	25%
FitTech	6706	TWD	157	201	Buy	28%	401	119%	30%

Note: Priced as of 3 March 2021.
Source: Bloomberg, HSBC estimates

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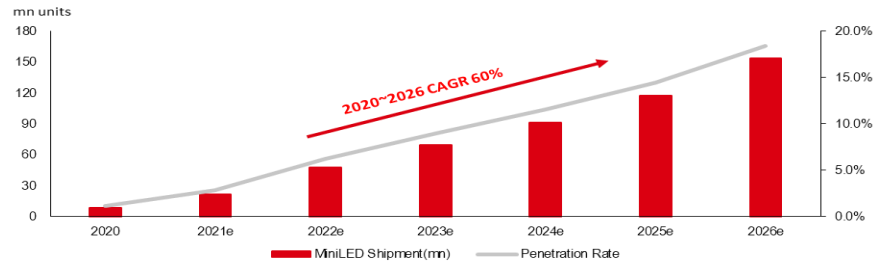
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Mini LED snapshot

Exhibit 1: Mini LED shipment growth forecasts for large and medium-sized applications



Source: OMDIA, HSBC estimates

Exhibit 2: Select beneficiaries of mini LED used as a backlight

Timeline	Introduction		Growth
	2020-22e		2023-26e
Beneficiary	Low yield and low demand	Stable yield but low demand	High yield and growing demand
LED	**	***	**
LED testing & sorting equip.	***	***	***
Mass transfer + die bonding process	**	***	***
Mass transfer equipment	***	***	***
LCD/PCB substrate	*	*	*
LCD/LED driver IC	*	*	*
Time controller IC	**	**	**
Lamination	*	*	*
Backlight	*	*	*

Source: HSBC estimates

Exhibit 3: Apple LED supply chain timeline

Supply chain	1H21	2H21	1H22	2H22
LED	Ennostar	Ennostar	Ennostar	Ennostar
LED probing and sorting equipment	FitTech	FitTech	FitTech	FitTech
SMT	TSMT	TSMT	TSMT	TSMT
Mass transfer equipment	Rohinni	Rohinni	Rohinni	Rohinni
PCB substrate	ZDT	ZDT	ZDT	ZDT
LCD panel	LGD	LGD	LGD	LGD
LCD driver IC	Sharp	Sharp	Sharp	Sharp
LED driver IC	Synaptics	Synaptics	Synaptics	Synaptics
Time controller IC	TI	TI	TI	TI
Backlight	Parade	Parade	Parade	Parade
Lamination	Heesong	Heesong	Heesong	Heesong
	GIS	GIS	GIS	GIS
	Radiant	Radiant	Radiant	Radiant
	GIS	GIS	GIS	GIS
	LGD	LGD	LGD	LGD

Source: HSBC estimates

Exhibit 4: Dominant display technology in each application and segment

		2020	2021e	2022e	2023e	2024e	2025e	2026e
Smartphone	High-end	RGB OLED						
	Mid-end	LCD	RGB OLED					
	Low-end	LCD						
Tablet/ Notebook	High-end	LCD	Mini LED					
	Mid-end	LCD					Mini LED	
	Low-end	LCD						
Automotive	High-end	RGB OLED				Mini LED		
	Mid-end	LCD				RGB OLED		
	Low-end	LCD						
TV	High-end	White OLED	Mini/Micro LED					
	Mid-end	LCD				Mini/Micro LED		
	Low-end	LCD						

Source: HSBC estimates

Three reasons why mini LED has a bright future

Once Apple leads the way,
we anticipate many others
will follow

(1) Apple to adopt mini LED in iPads and MacBooks

This is a huge development. Apple is set to start using mini LED backlight technology in its products – in 2021e we expect a 4% penetration rate for iPads and a 11% penetration rate for MacBooks. We believe this decision is based on: (1) better quality in terms of the range of colours, higher contrast ratio, and narrower bezel; (2) market positioning of products; (3) sufficient support in the supply chain is now available; and (4) market feedback and preparation for the future introduction of micro LED. Once Apple leads the way, we anticipate many others will follow, with huge implications for the mini LED market and the related supply chain.

(2) It will give the whole supply chain a new lease of life

LED and LCD panel makers have had a tough time in recent years. The main problems have been increased competition as more companies enter the market, slower growth in demand for products like smartphones, IT applications and TVs, and the maturing of the OLED industry. As mini LED and micro LED are extensions of traditional LCD technology, the adoption of mini LED will give the whole supply chain a new lease of life. The supply chain is diverse and complex, comprising companies in a range of LCD-related industries with many different skillsets, levels of technology capacity, and investment scale.

(3) Mini LED is the pathway to micro LED display technology

Micro LED is the next step after mini LED, giving the technology transition even more legs. As the manufacturing process is similar, the adoption of mini LED will smooth the way for the production of higher performance micro LED. The two can also co-exist as some large applications do not need super high resolution, so mini LED will be sufficient.

What about timelines?

Investors want to know how
long it will be before these
innovations are used in
mainstream products

While the market always welcomes new technologies, one of the first questions investors ask is how long will it be before these innovations are used in mainstream products? In this section we look at the timelines for micro and mini LED as well as expectations for OLED.

(1) Apple is also looking at OLED as a candidate for IT applications: It may take three years

The OLED technology used by Apple in iPhone screens is RGB-OLED, which uses individual sub-pixels emitting red, green, and blue light (hence RGB). We think Apple may also be considering this technology for IT applications in medium-size products like tablets, notebooks, and monitors. However, this transition could take up to three years, in our view.

The major challenges include: (1) 6 generation (G6) glass manufacturing facilities are perfect for producing economies of scale for applications used in smartphones, but costs increase for larger applications; (2) there is currently not enough qualified RGB-OLED available in the supply chain; (3) the uniformity and yield of medium-size RGB OLED is not as good as LCD; and (4) although the product life cycle of IT applications is longer than that of smartphones, OLED material has a shorter lifespan compared to LCD.

Progress is being made and OLED suppliers are already improving the yield rate for larger products. For example, the burn in rate – the gradual degradation of pixels that determines the life span of a product – has slowed over the past three years. But, in our view, creating economies of scale will require more G8 glass manufacturing facilities, and this will take time.

Once display makers start to discuss expanding G8 RGB OLED capacity with equipment suppliers, it takes about six months to produce the first sample. Fine-tuning the specifications usually takes another six months, and the equipment suppliers will then need another year to receive the necessary qualifications and move on to the mass production stage.

At the same time, while this manufacturing process is unfolding, we think advances in R&D will help resolve the technical issues related to using RGB OLED for products like tablets, notebooks, and monitors. All in all, we estimate three years to be a realistic timeline.

(2) How long will it be before micro LED starts to challenge mini LED? About five years

We think mini LED backlight technology has at least five more years to increase its penetration rate in medium-sized applications. First, as discussed above, we don't anticipate that RGB OLED will challenge mini LED in this area over the near term. Second, as mini LED becomes more widely adopted, the market for the technology will expand, especially in TVs. As more suppliers gain more manufacturing experience, the cost structure and quality will improve, making mini LED more competitive.

Forecasting how long it will
take for advances in R&D to
bear fruit is always difficult

Forecasting how long it will take for advances in R&D to bear fruit is always difficult. For example, it took Samsung Display Corporation (SDC) (Private) around 10 years to deliver mature RGB OLED for smartphones. Given advances in the development cycle, we think five years is a reasonable estimate for the length of time needed to deliver mature micro LED display. We no longer think of mini LED as the transition to micro LED but rather the foundation of micro LED.

(3) Mini LED and micro LED can eventually co-exist

There are currently two types of mini LED – a backlight solution and a display solution. We think more suppliers will start to use the backlight solution to achieve a higher yield rate thanks to an easier manufacturing process. Mini LED is already used as a display solution for large applications such as outdoor signage, taking market share from traditional LCD. As mentioned earlier, some large applications may not need to adopt micro LED and mini LED will suffice in terms of the quality of resolution required. This is why we think mini LED will still have a future after micro LED is developed, especially once the cost structure improves.

Who will be the winners in the mini and micro LED era?

The roll out of mini and micro LED is going to be a long process. And while it has great potential for the whole supply chain, we think progress may be uneven in terms of product quality, upgrades, and levels of profitability, especially during the development stage. However, to begin with, we think the yield rate and volume will be the most important factors in selecting the first round of winners (Exhibit 5). We now drill down into what this means for different parts of the supply chain.

Exhibit 5: Select beneficiaries of mini LED as backlight during tech evolution

Timeline	Introduction		Growth	Maturity
	2020-22e		2023-26e	2026e-
	Low yield and low demand	Stable yield but low demand	High yield and growing demand	High yield and high demand
LED	**	***	**	**
LED probing and sorting equipment	***	***	***	**
Mass transfer + die bonding process	**	***	***	**
Mass transfer equipment	***	***	***	**
LCD/PCB substrate	*	*	*	*
LCD driver IC	*	*	*	*
LED driver IC	*	*	*	*
Time controller IC	**	**	**	**
Lamination	*	*	*	*
Backlight	*	*	*	*

Note: ***The largest beneficiary, *The smallest beneficiary.
 Source: HSBC estimates

(1) The LED industry: Testing and sorting solution suppliers to benefit the most initially

Clearly, LED suppliers are set to benefit as demand for mini and micro LED increases, which should also push up the average selling price (ASP). The leading players have an advantage in terms of higher and more uniform mass production yields. However, we think price competition among LED suppliers will increase because: (1) As a backlight solution, LED is estimated to account for 30% of mini LED, making it a target for cost reduction; (2) the LED industry is already overcrowded, so competition will become even more intense; and (3) LED suppliers that are followers in terms of time to market appear to have lower ASPs but gain market share. As a result, we think LED suppliers will need more time than other beneficiaries in the supply chain before the high growth in mini LED is reflected in their earnings.

We prefer the testing and sorting solution suppliers as they stand to benefit directly from increases in LED quantity and higher function speeds required. As mini and micro LED applications become more mainstream, LED suppliers will need to expand their capacity in metal organic chemical vapour deposition (MOCVD) capacity, a process used to create high purity crystalline compound semiconducting thin films. They will also need to reduce LED sizes in order to get more chips. This, in turn, will increase demand and raise quality standards for LED testing and sorting equipment.

So, while LED suppliers enjoy some growth in content value, the increase in wafer shipments will be limited. Meanwhile, the LED testing and sorting equipment suppliers will benefit from growth in both content value and equipment shipments. There are several reasons why LED suppliers will benefit from growth in both content value and shipments.

- (1) The smaller size of LED may make existing equipment outdated and redundant.
- (2) Flip chip packaging is currently more suitable for mini LED, so the new sorting equipment may make the whole manufacturing process more efficient.
- (3) The process time for traditional probing & testing and sorting equipment is lengthy. But efficiency is important for mini/micro LED, so equipment with high speed functions may save time and boost output.

In our report published 5 March 2021, we initiate coverage on FitTech (6706 TT), an LED testing and sorting solution provider, with a Buy rating, see [Ready to ride the mini LED wave](#).

(2) Mass transfer: The right technology in the right era, but the yield rate is challenging

In our view, mass transfer and die bonding are the most difficult processes in the new mini and micro LED era. We see it as a major bottleneck and it will be a key factor in determining how fast the pace of mini and micro LED penetration accelerates. Mass transfer refers to the transfer of millions of micro-LED devices from a growth substrate to a target substrate to provide electrical connection and mechanical support. Die bonding is a manufacturing process used in the packaging of LEDs. It is the act of attaching a die (or chip) to a substrate or package by epoxy or solder.

The big issue is surface-mount technology (SMT), in which electrical components are mounted directly onto the surface of a printed circuit board (PCB) and allows more components to fit on a given area of substrate. Although this technology is widely available, we think only suppliers with the very latest equipment will be able to handle the challenges created by the switch to mini and micro LED technology. A lot of financial muscle will be required, too, because large amounts of capex will be required and yields will be low to begin with. We think mass transfer and SMT suppliers will benefit only after mini/micro LED products achieve decent volumes.

In our reports published 5 March 2021, we initiate coverage on TSMT (6456 TT), a leading SMT player, with a Hold rating, see [The lift from mini LED will take time](#), and Radiant (6176 TT), a leader in LCD backlight technology, with a Hold rating, see [Stable for now but lacks a catalyst](#).

(3) Display makers: Not major beneficiaries, but there are still some quality names

The display sector includes panel makers, suppliers of integrated circuits, and backlight suppliers. We think it is a relatively low value-added area when it comes to mini/micro LED technology compared to traditional LCD. However, there are some niche areas that are exceptions.

For example, controlling brightness, contrast, and power consumption is an important part of the mini LED manufacturing process. Parade Technologies (4966 TT, TWD1,255, Buy) specialises in highly integrated, high-performance display subsystem integrated circuits and is a leading supplier of display timing controller integrated circuits (ICs). We also like GIS (6456 TT, 113, Buy) because it has an additional manufacturing process in terms of mini LED design – backlight + lamination rather than purely lamination.

See [Parade Technologies: Buy: Multiple growth catalysts in 2021-22e](#), published 4 February 2021. In our report published 5 March 2021, we initiate coverage on GIS (6456 TT) with a Buy rating, see [Displaying positives, major drag gone](#).

Exhibit 6 illustrates all our timeline forecasts for the Apple mini LED supply chain for 2021-23e.

Exhibit 6: Apple mini LED supply chain timeline forecast

Supply chain	1H21e	2H21e	1H22e	2H22e	2023e
LED	Ennostar	Ennostar	Ennostar Osram	Ennostar Osram (San-an)	Ennostar Osram (San-an)
LED probing and sorting equipment	FitTech	FitTech	FitTech	FitTech	FitTech
SMT	TSMT	TSMT	TSMT	TSMT Radiant (Luxshare/GIS)	TSMT Radiant (Luxshare/GIS)
Mass transfer equipment	Rohinni	Rohinni	Rohinni	Rohinni	Rohinni
PCB substrate	ZDT YongPong	ZDT YongPong Compeq	ZDT YongPong Compeq	ZDT YongPong Compeq	ZDT YongPong Compeq
LCD panel	LGD Sharp	LGD Sharp	LGD Sharp	LGD Sharp	LGD Sharp
LCD driver IC	Synaptics	Synaptics	Synaptics	Synaptics	Synaptics
LED driver IC	TI	TI	TI	TI	TI
Time controller IC	Parade Heesong	Parade Heesong	Parade Heesong	Parade Heesong	Parade Heesong
Backlight	GIS	GIS	GIS	GIS	GIS
Lamination	Radiant GIS LGD	Radiant GIS LGD	Radiant GIS LGD	Radiant GIS LGD	Radiant GIS LGD

LED	LED probing and sorting equipment	SMT	Mass transfer equipment	PCB substrates
Ennostar (3714.TT)	FitTech (6706.TT)	TSMT (6278.TT)	Rohinni	ZDT (4958.TT)
Osram (OSR.DE)		Radiant (6176.TT)		Young Poong (000670.KS)
Sanan (600703.CH)		Luxshare (002475.CH)		Compeq (2313.TT)
		GIS (6456.TT)		Unitech (2367.TT)

LCD panel	LCD driver IC	LED driver IC	Time controller	Backlight	Lamination
Sharp (6753.JP)	Synaptics (SYNA.US)	TI (TXN.US)	Parade (4969.TT)	Heesong	GIS (6456.TT)
LGD (LGD.TO)				GIS (6456.TT)	LGD (LGD.TO)
				Radiant (6176.TT)	

Source: HSBC estimates

We have initiated coverage on FitTech, TSMT, GIS, and Radiant

FitTech (6706 TT), Buy

FitTech is an LED testing and sorting solution provider. We believe it will be one of the biggest beneficiaries of the mini LED era, thanks to higher demand for both the quantity and quality of LED. Take notebooks, for example. Compared to traditional LCD, mini LED uses 500x times more LED, and the ASP is 20-30% higher thanks to higher specifications. FitTech could also benefit further if downstream mass transfer suppliers need more LED units because of a low yield rate.

As mentioned earlier, yield and volumes are likely to be the factors that determine the profitability of some suppliers. We think this does not apply to FitTech because: (1) it is the market leader in testing and sorting, so function speed and accuracy of the equipment are the most important factors; and (2) the company has the ability to adjust idle capacity to balance utilisation rates because some mini LED equipment can also be used for traditional LED.

Valuation and risks

	Valuation		Risks to our view
FitTech 6706 TT Buy	Current price:	We forecast FitTech EPS of TWD9.55/12.5 in 2021/22e. Our TP of TWD201 is derived by applying a 21x target PE multiple to our 2021e EPS estimate of TWD9.55. Our target price implies 28% upside from current levels; accordingly we initiate coverage on the stock with a Buy rating. That target PE of 21x represents FitTech's global competitors' PE average. As all of FitTech's equipment are mainly competing with global companies, and its net income CAGR is at 32% during 2018-21e vs. -6% during 2017-20e, we believe 21x PE is justified for FitTech.	Key downside risks: (1) Intense price competition among competitors; (2) faster technology innovation by competitors; (3) payments postponed by clients; (4) shipping schedule delays or labour shortages due to COVID-19; (5) lower-than-expected end demand of mini LED products; (6) different business model between suppliers or clients; (7) slower-than-expected technology evolution; and (8) slower progress or higher expenses in new business/product development.
	Target price:		
	Up/downside:		

Note: Priced at 3 March 2021
 Source: Bloomberg, HSBC estimates

For further details, see [FitTech: Initiate at Buy: Ready to ride the mini LED wave](#), 5 March 2021.

GIS (6456 TT), Buy

As a leading player in display lamination, we think GIS will profit from the difference in display structure between traditional LED and mini LED. It has experience in LCD and strong relationships across the supply chain and with clients. This should give GIS the opportunity to expand its business from lamination, which is only used in the traditional LCD lamination business, to backlight + lamination used for mini LED. This could increase ASPs by 20-30%.

Aside from the increase in content value from mini LED business, we think the company's overall product mix will improve. Its iPhone business is about to finish because Apple has changed the iPhone display's design, so GIS's services are no longer needed. The launch of Apple's M1 chip will also boost demand for MacBooks, benefitting GIS directly.

Valuation and risks

	Valuation		Risks to our view
GIS 6456 TT Buy	Current price:	We forecast GIS EPS of TWD11.10/14.60 in 2021/22e. Our rounded TP of TWD168 is derived by applying a 13x target PE multiple to our 2021e EPS estimate of TWD12.96. Our TP implies +48.7% upside from current levels; accordingly, we initiate coverage on the stock with a Buy rating. Our target PE of 13x represents the stock's trading average during 2018-20e plus 1 SD. As GIS's net income CAGR is 26% during 2010-22e vs. -7% during 2018-20e, we believe 13x PE is justified thanks to GIS's upcoming growth momentum from increasing demand from iPads/MacBooks and new technology and products.	Key downside risks: (1) Price competition is more intense than expected, (2) more one-time write-off items from old manufacturing plants, (3) unfavourable FX, (4) yield rate of new business is lower than expected, (5) on-hand projects cancelled or postponed from clients, and (6) lower-than-expected end demand from new business.
	Target price:		
	Up/downside:		

Note: Priced at 3 March 2021.
 Source: Bloomberg, HSBC estimates

For further details, see [GIS: Initiate at Buy: Displaying positives, major drag gone](#), 5 March 2021.

TSMT (6278 TT), Hold

A leading player in surface-mount technology (SMT), we think TSMT will benefit from the mini LED trend, but it may take time. The issue here is that mass transfer and die bonding, the new manufacturing process involved, may have a low yield rate at the initial stage. As a result, we think TSMT will generate profits from the new business only once the yield rate improves. Volume could be another factor. As this new process is mainly designed for mini LED use and the overall gross margin of the SMT process is driven by production scale, TSMT's profit may also face pressure from limited mini LED volume at the initial stage.

Valuation and risks

	Valuation	Risks to our view
TSMT 6278 TT Hold	Current price: TWD115.00 Target price: TWD120.00 Up/downside: +4.3%	Key upside risk: (1) TSMT's yield rate is better than expected; (2) mini LED penetration rate is higher and faster than expected; (3) competitors' entrance is slower than expected; and (4) India fab progress is faster than expected. Key downside risks: (1) DRAM and TV application competition gets more intense and; (2) TV, notebook, tablet and server demand slows down.

Note: Priced at 3 March 2021.
 Source: Bloomberg, HSBC estimates

For further details, see [SMT: Initiate at Hold: The lift from mini LED will take time](#), 5 March 2021.

Radiant (6176 TT), Hold

A leader in LCD backlight technology, we think the growth opportunity from mini and micro LED will be limited. Radiant has not invested much in the new process required for this new technology, preferring to play it safe. We believe this will limit future growth. We suggest investors be overweight Radiant when the company decides to invest new businesses on a significant scale.

Valuation and risks

	Valuation	Risks to our view
Radiant 6176 TT Hold	Current price: TWD118.00 Target price: TWD133.00 Up/downside: +12.7%	Key upside risks: (1) Faster progress in new business investments, and (2) higher-than-expected iPad and MacBook demand. Key downside risks: (1) Lower-than-expected GMs, and (2) faster-than-expected new technology replacement from traditional LCD.

Note: Priced at 3 March 2021.
 Source: Bloomberg, HSBC estimates

For further details, see [Radiant: Initiate at Hold: Stable for now but lacks a catalyst](#), 5 March 2021.

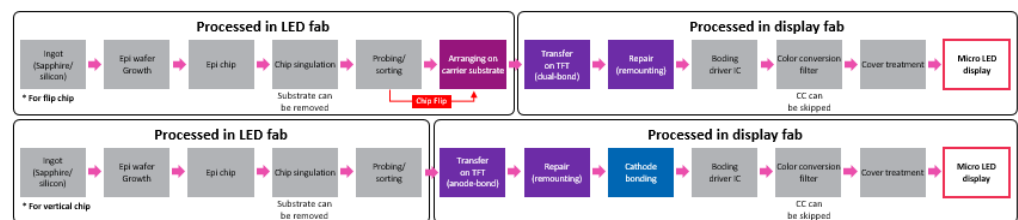
Manufacturing process and value-add in mini LED

Mini LED and micro LED – similar manufacturing process

Essentially, the process for making mini LED is a simpler version of the one used for micro LED (Exhibit 7). The main technical differences are the size and quantity of the chips needed, and the accuracy of mass transfer.

Cost is an entirely different matter – making micro LED is 20x more expensive. The root cause is the yield rate and processing time. For suppliers, we think the key to profitability will be to achieve economies of scale for both mini and micro LED.

Exhibit 7: Manufacturing process of micro LED display



Source: OMDIA

Step 1: LED epitaxial and mini size cutting – smaller size and higher quality requirements will give LED suppliers more value-add in the mini LED era.

- ◆ With smaller LED, it is more difficult to maintain the emitting efficiency and there may be more defects due to the complexity of LED layer structure. The quality of LED may impact the entire mini/micro LED product manufacturing process, making the LED supplier more important than before.
- ◆ In terms of LED packaging, we think flip-chip with chip on board (CoB) can achieve smaller pitch size LED than traditional face-up surface mounted devices (SMD) or package on board (PoB), based on current technology.

Step 1-1: LED probing and testing and sorting process before shipping to die bonding – higher demand for LED quantity and quality to benefit equipment suppliers.

- ◆ In order to achieve higher quality, smaller LED, the probing & testing and sorting process that takes place before LED packaging and die attachment will be much more important than for traditional LCD.

Step 2: Mass transfer the LEDs and bond onto target substrate – the most difficult and thus the most value-added process.

- ◆ There are several challenges involved and this could become the industry bottleneck. (1) The amount of time involved in the whole manufacturing process; (2) greater precision required for LED pitch and; (3) a difficult repair process. These are the main reasons why mini/micro LED display costs are so high.

Step 3 (in mini LED as backlight): Laminate LCD with mini LED board – Display and driver ICs are not that different, but LED driver and time control may be critical.

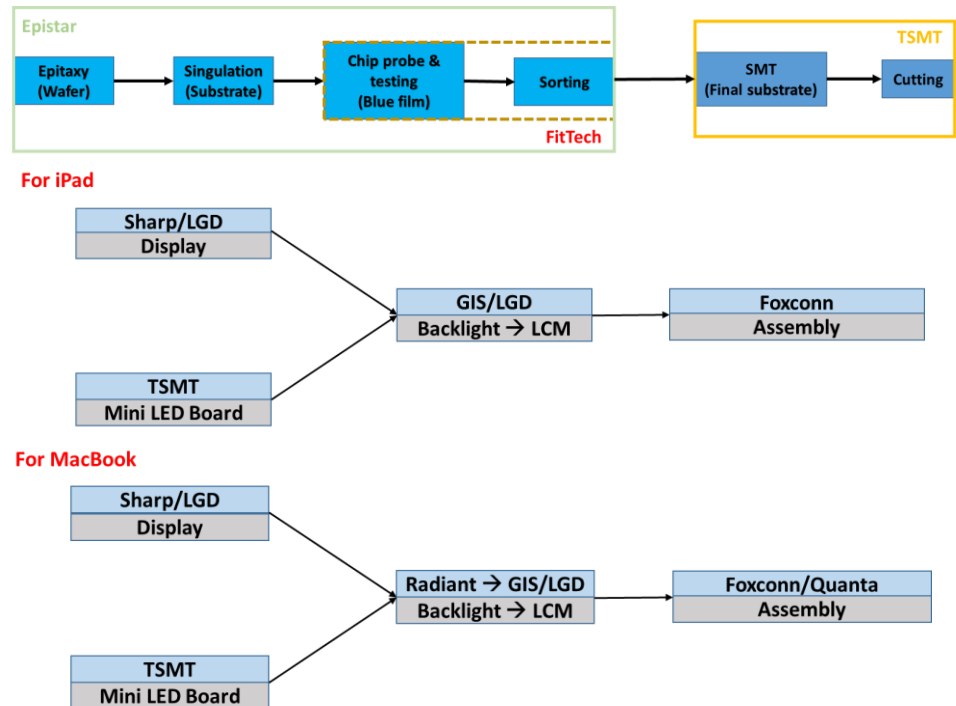
If it is mini/micro LED used as display, step 3 is to laminate mini/micro LED display with other optic layers and cover glass.

- ◆ If mini LED is the backlight solution, then there may not be a big difference between mini LCD and traditional LCD. If mini or micro LED is the display solution, then LCD is no longer needed.

Apple's first mini LED products may set the industry standard

Exhibit 8 illustrates what we think the manufacturing process and supply chain for Apple's first mini LED products could look like. We expect the manufacturing process to become the industry standard.

Exhibit 8: This is what we think the manufacturing process and supply chain for Apple's first mini LED products could look like



Source: HSBC

Medium-sized applications may be the turning point for mini LED

No one dominant technology

There's no one "killer technology" in the display industry and each has its own advantages and cost structure. For example, some are restricted by size. RGB OLED is more suitable for small applications and white OLED better for larger sizes. We now look at the options available, depending on size.

Small size: OLED is best for high-end smartphones

OLED display has dominated high-end smartphones ever since Apple used it for the iPhone X in 2017. It has better image quality, lower power consumption, and a thinner design. As investment in OLED increased and the technology advanced, OLED display has also been used for mid-end smartphones. We think it will stop there. Given the low cost and sufficient supply, we think low-end smartphones will still adopt LCD display.

Looking ahead, we expect micro LED to eventually become competitive with RGB OLED in smartphones thanks to the advanced features it offers (Exhibit 9). However, much will depend on how quickly the cost of micro LED falls.

Large size: LCD still dominant, but micro and mini LED starting to emerge

While LCD still dominates this part of the display market, we think the future lies in micro and mini LED, given the wider range of colours offered, better brightness, lower power consumption, and greater reliability. However, due to the complexity of the micro LED manufacturing process, this is going to take some time. We believe the supply chain will use mini LED as a stepping stone for micro LED.

There is evidence that this is already happening. Some projects in the TV sector have already adopted mini LED and last year SEC (005930.KS, KRW82,500 ,Buy) and LGE (066570.KS, 148,800, Hold), big clients of major OLED suppliers, both announced plans for large (over 110") micro LED TVs. LGE has also indicated it will also make mini LED TVs.

Mini LED TV may not have the same high-quality resolution as micro LED, but it offers a better range of colours, higher contrast, and slimmer border than traditional LCD. It also outperforms in terms of brightness and product life time compared to white OLED. That's why we think mini LED will retain a position in the market even when micro LED becomes more established because mini LED will always be cheaper than micro LED.

Medium size: The turning point for mini LED?

This part of the market covers tablets, notebooks, automotive applications, and monitors. What's important here is that no one display technology is dominant. We think that's because the segment is not as big as TVs or smartphones. For example, RGB OLED has better quality in small-size display but quality becomes inconsistent in large sizes. Micro LED may have relatively lower costs in large applications but the cost soars in small applications (for now). That's why we think the medium-size market may represent the turning point for mini LED.

We see huge growth potential here and our unit forecasts for different categories in 2021e are as follows – tablets + notebooks 350-400m, automotive 145-150m, and monitors 140-150m. This totals are around 650m units, up from c600m in 2020.

As shown in Exhibit 10, it is clear that mini LED used as a backlight already has a foothold in the TV category. We expect demand to rise rapidly as mini LED is adopted in a wider range of products in the medium-size market.

Exhibit 9: Mini LED product list in 2020-21e

Application	Size resolution	Set	
		Set maker	Model
TV	65" 3840x2160	TCL	8-series X10
Monitor	31.5" 3840x2160	ASUS	PA32UCX
Monitor (Medical)	31.5" 3840x2160	Dell	
Monitor	31.6" 6016x3384	Apple	Pro Display XDR
TV	55/65/75" 3840x2160	TCL	6-series Roku
Note/PC	17.3" 3840x2160	MSI	Creator 17 mini LED
TV	80" 7680x4320	LG Electronics	
TV	75" 7680x4320	Konka	
TV	75/85" 7680x4320	TCL	Vidrian 8
TV	75" 7680x4320	Changhong	ChiQ Mini
Monitor	31.5" 3840x2160	Dell	UP3221Q
Monitor	31.5" 3840x2160	Acer	Predator X32
Monitor	27" 3840x2160	Lenovo	ThinkVision Creator Extreme P27
TV	75" 7680x4320	Samsung VN	
TV	80+" 7680x4320	Hisense	
Tablet	12.9" 2732x2048	Apple	iPad Pro
TV		TCL	
TV		TCL	
Automotive	34" 6720x1620	Cadillac	Lyriq EV

Source: OMEDIA

Cost analysis and mini LED penetration in each application

Based on cost analysis by OMDIA, a global tech research company, and our own estimates, we conclude that:

- ◆ Micro LED will still cost 20x more to produce than other display technologies in five years unless a game-changer emerges. This will give mini LED more time to develop.
- ◆ Mini LED may have a more competitive cost structure in two years, which should accelerate its adoption as a backlight solution. The cost of mini LED as a backlight solution is about 2x higher than that of OLED, but about 3x higher than traditional LCD. We think the cost of mini LED as a backlight will fall to that of OLED around 2023-24e.
- ◆ TV is the easiest category for mini LED to penetrate. Tablets, notebooks, automotive applications, and monitors are set to follow as mini LED costs fall.

Mini and micro LED: Another opportunity in larger applications

The maximum size of traditional LCD is currently limited to about 110". We think this represents another entry point for mini and micro LED technology. The cost gap with traditional LCD is smaller, particularly in really large applications such as outdoor signage.

Exhibit 10: Mini LED backlight: Pros and cons for LCD, OLED, and micro LED

	vs. LCD/OLED		vs. micro LED	
	Pros	Cons	Pros	Cons
In general	No burn-in	Expensive cost	- Cheaper cost - Easy to manufacture	Thickness
TV	- Combine benefits of LCD (high resolution and brightness) and OLED (high contrast ratio) - Perfect narrow bezel with slim design	- Cost becomes higher for better HDR and slimmer design - Thicker than OLED	Flexibility in size while mid/small-size micro LED displays are hard to get	- Color gamut - Brightness
Monitor	- High-performance HDR adequate for gaming and professional monitors - Better color gamut	- Halo image defect - Still thicker than edge backlighting	Ease of manufacturing while micro LED displays become more difficult with smaller chips	Halo image defect
Notebook PC and tablet	- Local dimming, which has not been available for edge-backlit LCDs - Perfect narrow bezel - Better color gamut	- Still thicker than edge backlighting - Power consumption - Halo image defect	- Ease of manufacturing while micro LED display becomes more difficult with extremely small chips - Power consumption	Halo image defect

Source: OMDIA

Cost and total addressable market analysis: TVs, automotive, and tablets/notebooks

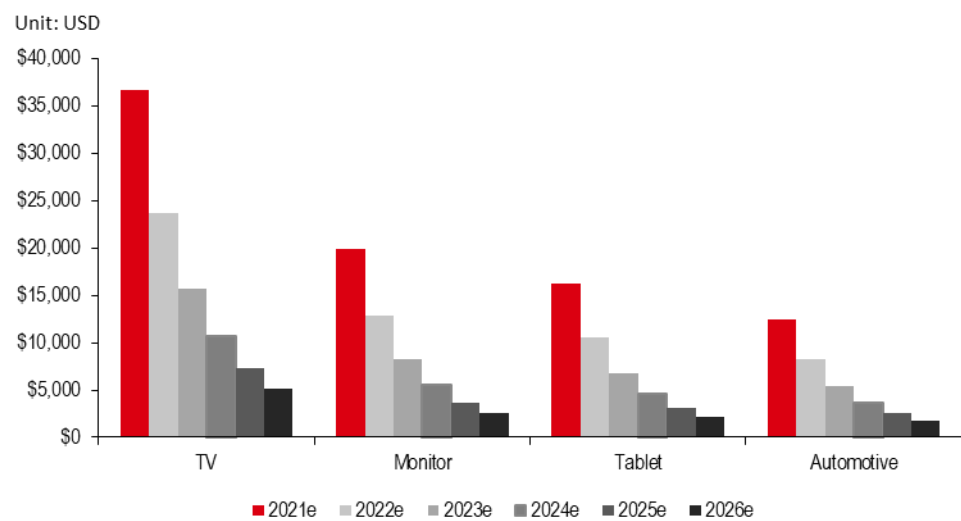
A wide range of factors affect the cost structure of mini and micro LED – chip size, chip numbers (resolution and zones), monochrome or RGB chip, backplane (a group of electrical connectors in parallel with each other), and the repair process. We provide a cost comparison for each application, assess their respective total addressable market (TAM), and make growth forecasts up until 2026e.

We put the main focus on mini LED in this section as we see this as the pathway that will lead to the micro LED era. For mini LED, we concentrate on its use as a backlight solution as the technology is already being used.

Specifically, we compare the cost structure for traditional LCD, OLED (white OLED for large size, RGB OLED for the rest), and mini LED in the following categories – TV, automotive, and tablet/notebook applications.

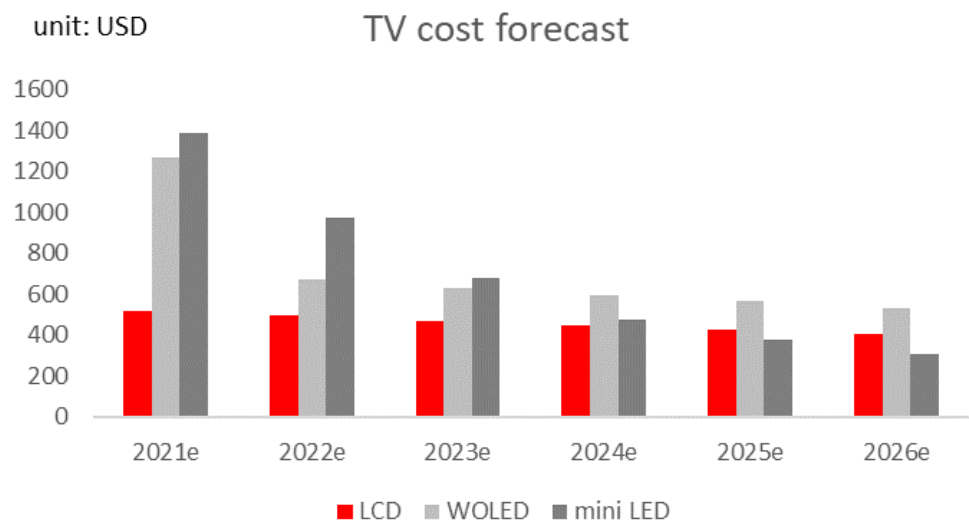
One of our key assumptions is that the cost of mini LED technology will fall 30% every year as it is easier to reduce costs for new technologies in the first few years. For the more mature technologies, we forecast OLED costs to decline 10% and for LCD costs to fall 5% every year.

Exhibit 11: Micro LED cost forecast for each application – 20x that of mini LED even in 2026e

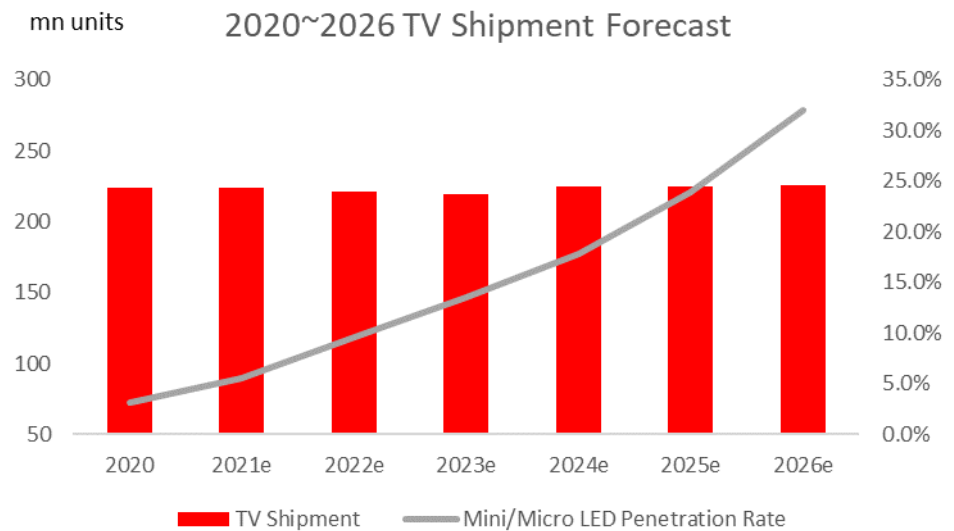


Source: OMDIA, HSBC estimates

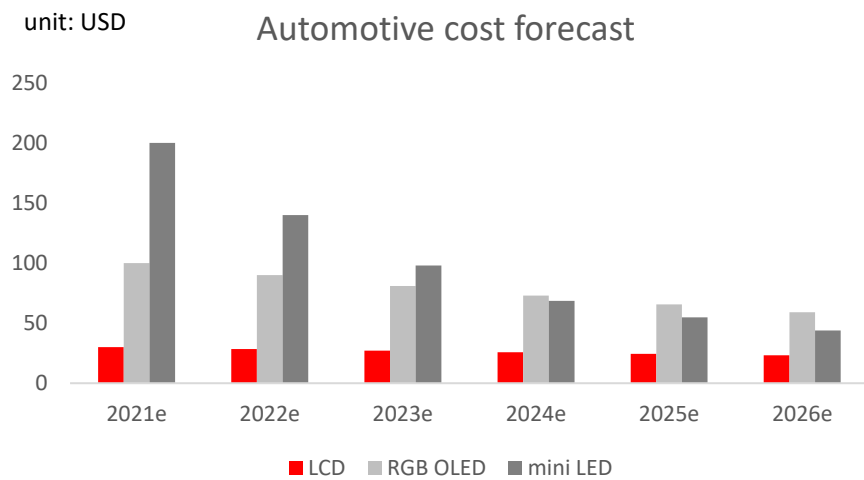
Exhibit 12: Display cost analysis in the TV segment



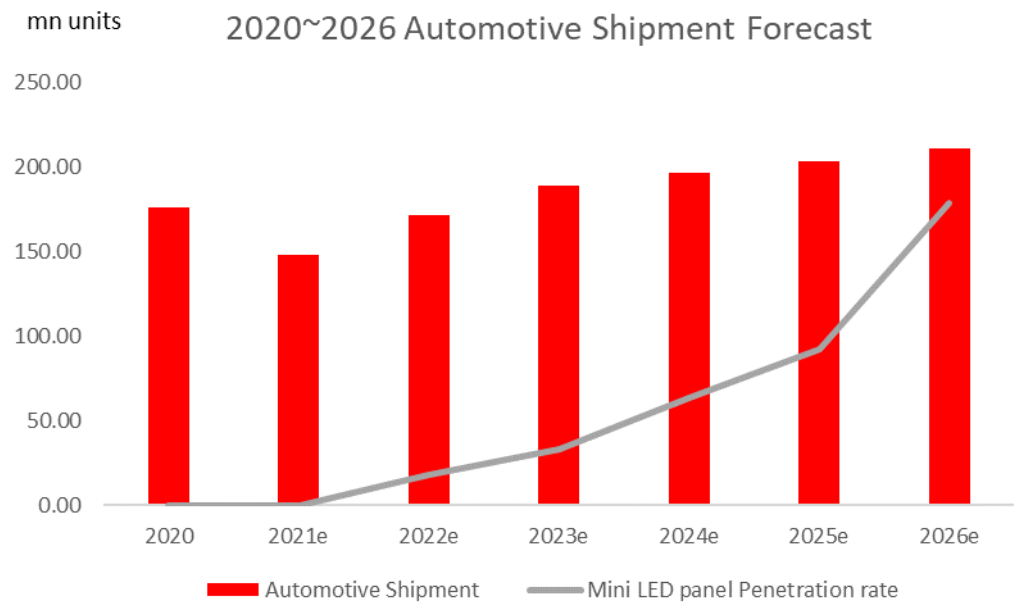
Source: OMDIA, HSBC estimates

Exhibit 13: TV market TAM and mini/micro LED penetration rate


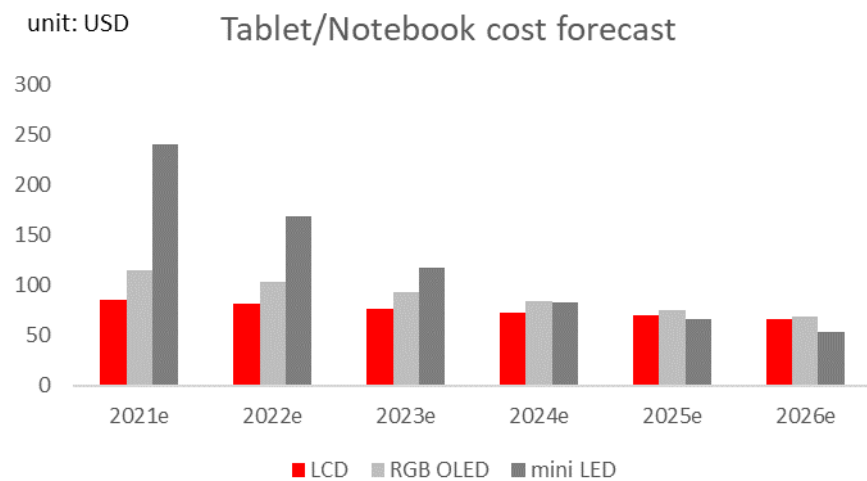
Source: OMDIA, HSBC estimates

Exhibit 14: Display cost analysis in the automotive segment


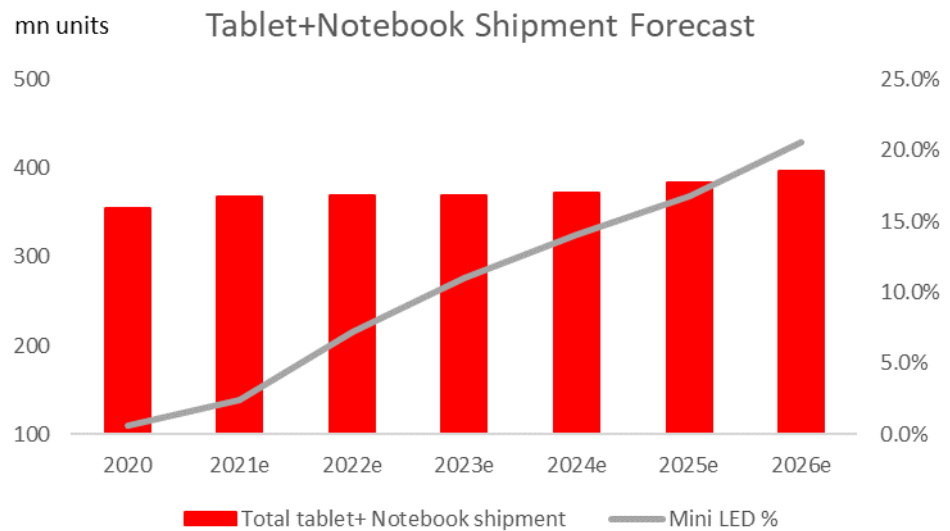
Source: OMDIA, HSBC estimates

Exhibit 15: Automotive market TAM and mini LED penetration rate


Source: OMDIA, HSBC estimates

Exhibit 16: Display cost analysis in the tablet/notebook segment


Source: OMDIA, HSBC estimates

Exhibit 17: Tablet/notebook market TAM and mini LED penetration rate


Source: OMDIA, HSBC estimates

Conclusion

As we think RGB OLED may retain its dominant position in small application (mainly smartphones), we believe mini LED will gradually take over in the area of medium-sized applications such as tablets, notebooks, and automation. We also think the penetration rate of mini LED will rise in large applications, mainly TVs, once costs start to fall sharply in 2-3 years.

Exhibit 18: Dominant display technology in each application and segment

		2020	2021e	2022e	2023e	2024e	2025e	2026e
Smartphone	high-end	RGB OLED						
	mid-end	LCD	RGB OLED					
	low-end	LCD						
Tablet/ Notebook	high-end	LCD	Mini LED					
	mid-end	LCD					Mini LED	
	low-end	LCD						
Automotive	high-end	RGB OLED				Mini LED		
	mid-end	LCD					RGB OLED	
	low-end	LCD						
TV	high-end	White OLED	Mini/Micro LED					
	mid-end	LCD					Mini/Micro LED	
	low-end	LCD						

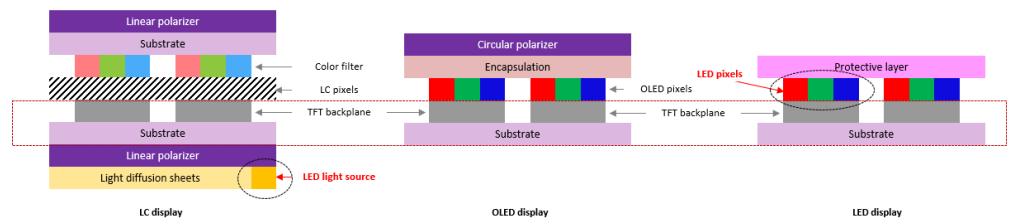
Source: HSBC estimates

Appendix: An introduction to display technology

Liquid crystal display (LCD), mini and micro light-emitting diode (LED) are all LED-based displays. They are different from organic light-emitting diode (OLED) technology. For example, the main difference between an LED TV and an OLED TV is that the pixels of an OLED TV are self-illuminating, and the LEDs in an LED TV are used to light an LCD display.

LCD is the most common display technology, representing 65-70% of industry value.

Exhibit 19: Display structure of LCD, OLED, and micro LED



Source: OMDIA

Micro LED may be the ultimate display technology in the future, but there is a long way to go

Exhibit 20 compares LCD, OLED, and micro LED. It is clear that micro LED has many advantages but costs are much higher. Despite this, as costs fall we think micro LED is the future for the display industry.

- ◆ For small applications, power consumption and high resolution are the key features; micro LED outperforms RGB OLED.
- ◆ For medium-sized applications, power consumption and high contrast ratio are the most important; micro LED outperforms traditional LCD.
- ◆ For large applications, brightness and contrast are key for different applications; micro LED outperforms traditional LCD, white OLED and QD display, which is used in LED-backlit LCDs.

Exhibit 20: Comparison of LCD, OLED, and micro LED

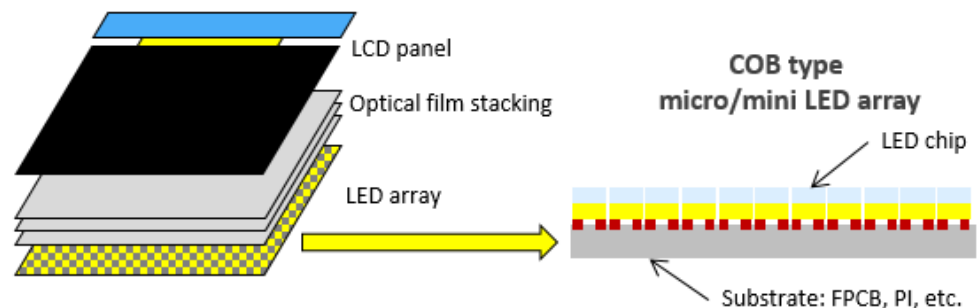
	LCD	OLED	Micro LED
Mechanism	Colour filter + back light	Self-emissive	Self-emissive
Luminance efficiency	Low	Medium	High
Luminance	> 3x10 ³ (full colour) > 1x10 ⁴ (green)	> 5x10 ² (full colour) > 1x10 ³ (yellow)	> 1x10 ⁵ (full colour) > 1x10 ⁷ (blue/green)
Contrast ratio	Medium	High	High
Response time	Millisecond	Microsecond	Nano-second
Power consumption	Medium	Medium	Low
Operating temperature	-20–80°C	-30–70°C	-100–120°C
Shock resistance	Low	High	Medium
Flexibility	Low	High	Medium
Life span	Long	Medium	Long
Cost	Low	Low	High
Water-oxygen resistance	High	Low	High

Source: OMDIA

Wider definition of mini LED to expand markets and lengthen the transition period

LED chips smaller than 100µm are referred to as micro LED while LED chips larger than 200µm are seen as traditional LCD. Previously, some institutions provided stricter definitions of mini LED in terms of LED size and chip type. However, we believe the market may widen the definition as more products using mini LED technology hit the market. That is to say, a full-array local dimming (FALD) LCD with a fine-pitch LED array could be seen as a mini LED application.

To differentiate between traditional SMD LED (surface mount device), a wider definition of mini LED should have at least a greater number of LEDs (>10,000 units), more zones (>1,000), and smaller LED size (<5 million). Mini LED as a backlight or display may both be currently deemed as mini LED applications as the only difference is the illuminance structure.

Exhibit 21: Mini LED as a backlight structure


Source: OMDIA

Disclosure appendix

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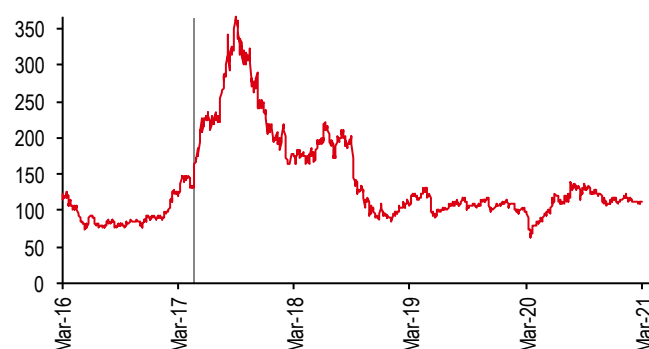
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Share price and rating changes for long-term investment opportunities

GIS (6456.TW) share price performance TWD Vs HSBC rating history



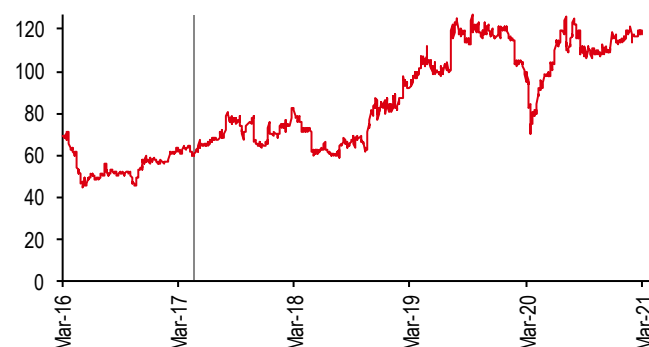
Source: HSBC

Rating & target price history

From	To	Date	Analyst
Buy	N/A	19 Apr 2017	
Target price	Value	Date	Analyst
Price 1	N/A	19 Apr 2017	

Source: HSBC

Radiant Opto-Electronics (6176.TW) share price performance TWD Vs HSBC rating history



Source: HSBC

Rating & target price history

From	To	Date	Analyst
Hold	N/A	19 Apr 2017	
Target price	Value	Date	Analyst
Price 1	N/A	19 Apr 2017	

Source: HSBC

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Company	Ticker	Recent price	Price date	Disclosure
GIS	6456.TW	113.00	03 Mar 2021	6
RADIANT OPTO-ELECTRONICS	6176.TW	118.00	03 Mar 2021	4, 7

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